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Electric Camera Visual Imaging System

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Abstract

The Advanced Design Program team at West Virginia University's Department of Electrical and Computer Engineering has designed and built an electric camera visual imaging system. The visual imaging system demonstrates the use of cpaciflector sensor data to form a computer generated picture. A tele-operated robot system can use the electric camera to scan a work area and form an image of the area. This imaging system frees the robot operator from the constraints of tradidional video camera systems, and increases the intelligence of the robot. The design centered on the individual components, but the arrangement of the subsystems is flexible. A focus was placed on electronic hardware, computer software, and noise reduction techniques.

1 Introduction

Tele-operated robotics research shows potential for many space applications, especially in assisted satellite repair and unmanned space station experiments. Such situations require mission specific designs and operations. However, these designs require the ability for complex, multi-task robot maneuvers. Using standard tele-operated robot systems, the robot operator relies on video camera images and force-torque sensor feedback.

The use of video cameras gives the robot operator a direct view of the workspace, but it has several disadvantages. Video camera vision is limited to the camera range and fixed camera angles; the view can be blocked by either the payload or the robot; and finally, the operator is limited by the two dimensional picture.

Capaciflector research being carried out at Goddard Space center shows potential for solving these problems. The capaciflector sensor is a type of capacitive sensor that measures distance. The finesse of the sensor relies on the electric fields which are utilized in the sensor measurements. This allows the robot to maneuver without touching the object until desired.

Since the sensor feedback is related to distance; the capaciflector can be utilized in computer imaging. This type of imaging not only gives the robot operator a three dimensional picture, but it relieves the operator's problems associated with video vision systems. This data can be used with pattern recognition, and image processing subroutines to enhance the robot's intelligence. Intelligence that may lead to automation of certain robot subroutines.

The West Virginia University electrical and computer engineering design team has designed and developed a prototype electric camera. The purpose of the electric camera project was to demonstrate the use of capaciflector sensors in visual imaging systems.

2 System Overview

The electric camera visual imaging system is displayed in block diagram form in Figure 1. This figure shows the four major subsystems of the camera: the sensor array and electronics, the microcontroller, the optical fiber Transmission, and the computer software.

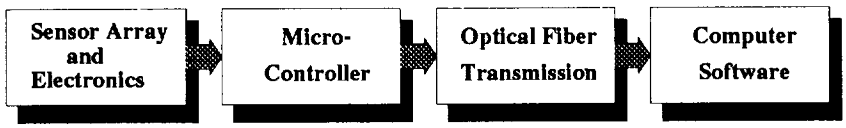

Fig. 1 System Block Diagram

The sensor array and electronics consist of a four by four array of capaciflector sensors. When this array is moved in a scan pattern by the robot, the computer uses the sensor measurement feedback to form an image of the work area. The sensor array is powered by the sensor electronics. These electronics consist of an oscillator, sensor and sheild drivers, and analog multiplexer, bandpass filters, peak detectors, and a differencd amplifier.

A micro-controller is used to control the timing of the sensor electronics, while the output signal from the electronics is collected through an A/D convertor. These values are then processed and transmitted over a fiber optic serial cable.

The information is received by a 486 computer. Software subroutines image process the raw data and generate a graphical representation of the work area. All of the subroutines and user interface modules are written in C and Matlab codes.

These individual sybsystems were designed using hardware design principles, software development methods, and noise reduction techniques. Each system component was designed speratly, so parallel design management and total system integration design methods had to be practiced.

3 Sensor Array Electronics

A crystal oscillator is used as a source generator for the sensor electronics. Capaciflector sensors require that both the sensor plates and shield plate be driven by a sinusoidal voltage source. A Colpitt-FET crystal oscillator configuration was chosen to generate a sinusoidal signal, and a unity gain, narrow bandpass filter was used to remove all harmonic distortions. The generated sine wave frequency was set by the 83 kHz resonance frequency of the crystal.

The sensor driver's and the shield driver's electronic configurations are shown in Figure 2. An operation amplifier holds the voltage of the sensor at the oscillator voltage. As the capaciflector is moved closer to a grounded object, the capacitance of the sensor increases. The one Mohm feedback resistor amplifies the voltage change across the sensor.

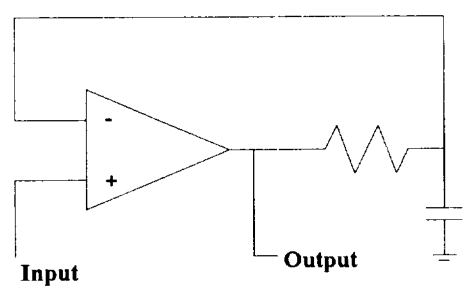

Fig. 2 Sensor/Shield Driver

The shield plate is driven at the same voltage as the sensor. The purpose of the shield is to keep the sensor from coupling with the ground plane behind the sensor and forcing the electric field from the sensor to couple outward with the object.

An analog multiplexer is used to time division multiplex the sixteen sensor output signals onto one line. Multiplexing the signals reduces the amount of redundant circuits in the system.

The output of the Mux is sent through a bandpass filter. The filter wasdesigned with a very narrow band and a unity gain at 83 kHz. This filter removes almost all of the noise from the signal. The filtered signal is then sent through a peak detector which captures the peak voltage of the signal. The peak voltage will be used to determine the voltage changes at the capaciflector.

Since the signal peak is being used to detect voltage changes, a reference voltage is needed. This reference voltage is created by using an operational amplifier in a standard, non-inverting configuration. The non- inverting amplifier is used to condition the oscillatior output voltage into a voltage signal equivalent to the voltage input of a sensor when it is not capacitively coupled to an object. This reference signal is passed through an identical filter and peak detection circuit.

The DC voltages from both peak values: one being the sensor signal, and the other being the voltage reference signal, are subtracted by a difference amplifier. The output of this amplifier is the voltage change of the sensor. This voltage change is the measurement that is being sent to the micro-controller.

4 Micro-Controller

A micro-processor controller board was used to collect sensor data, to control the sensor electronic timing, and to prepare and transmit the data to the computer. The capaciflector sensor values and a temperature sensor value are collected throught the A/D convertor on the controller board. The analog signals are converted to digital format and processed by the micro-processor.

A temperature sensor is used to measure the ambient temperature of the electronics, because small temperature changes can cause the sensor voltage to drift. A sensor voltage drift can greatly decrease the sensitivity of the capaciflector.

As each value is being read, the microprocessor controls the switching of the multiplexer, the charging and discharging of the peak detectors, and the timing of the reading to the A/D convertor. As an imaging scan is being made, the micro-controller reads the entire array four times, and it takes one temperature reading at each scan position. The micro-processor collects the four values for each sensor and averages them together using a simple median filtering routine.

Each sensor value is coordinated with its position value. The three data values: temperature reading, capaciflector voltage change, and the position values, are transmitted to the computer.

All computer transmission is performed through a standard nine pin RS-232 transmission port. The serial transmission is also controlled by the micro-processor.

5 Optical Fiber Transmission

An optical serial cable was designed to transmit data from the microcontroller to the computer. The thirty-two foot serial cable was designed using fiber optics because the optical cable can accomodate long transmission ranges without acting as an antenna or picking up stray noise.

Standard RS-232 line drivers are used to convert the RS-232 signals to TTL signals. The TTL data format is converted to an optical signal by Hewlett- Packard transmitters. The six signals are then transmitted over three ,plastic fiber, multimode, duplex cable. Matching Hewlett-Packard receivers convert the optical signal to a TTL electronic signal, and another line driver reconverts the TTL signal to the RS-232 format.

6 Computer Software

A C language subroutine was written to read the sensor data being transmitted to the computer serial port. This subroutine saves the transmitted data into an M file. This file is then utilized by the Matlab code.

All image processing routines and the user interface window were written using Matlab code. When the user interface window is activated and the data file is loaded, the Matlab subroutine formats the data into a matrix and prepares it for the filtering routines. The capaciflector has an exponential relationship between voltage and distance, so the initial data needs compensated.

The data is compensated a second time for temperature variation. This is done by using a temperature characteristic curve, and the temperature reading. After the data has been processed a median filtering routine takes weighted averages of the values in close proximity and replaces the center value with the median value. This type of filtering was chosen as an image processor because it removes most noise, while preserving the image edges. This can allow for edge detection and object recognition with the visual image.

Since the user interface window was written in Matlab, it has all the versatility of a Matlab window. The menu bar has normal Matlab options plus a 2-D or 3-D display option, online help, and a choice of filtered or raw data display screen.

7 Summary

The electric camera visual imaging system built by the WVU electrical and computer engineering ADP students displays the use of capaciflector sensors as a vision system. The focus of the design was on electronic hardware, computer software, and noise reduction methods. The proto-type that was built by the students displays all the major components required for such a system.

The design centered on the individual elements, but the arrangement of the subsystems is flexible enough to be customized for different robot systems and applications. The advantage of this visual imaging system over traditional video systems is that all the information is collected and stored in a computer. This gives the robot operator more flexibility in imaging the workspace environment. The storage of data in the computer also increases the intelligence of the robot, and it possibly gives rise to several new abilities to robot systems.